



# PERFORMANCE EVALUATION OF DRILLING TOOLS DURING MACHINING PLAIN CARBON FIBER REINFORCED POLYMER (CFRP)

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## ABSTRACT

The demand of CFRP have been arises because of their capabilities and high strength to weight ratio properties. It has been remarkably used in most field nowadays as an example in aerospace industries as it provide weight reduction and reduce the fuel consumption at the same time. However, the inherent anisotropy, inhomogeneous properties of CFRP and low bonding strength within the laminates make machining of these composite materials results in several undesirable effects such as delamination, burr and chipping. This experimental study was conducted on drilling CFRP using 3mm-diameter ball nose Diamond coated, Titanium Aluminum Nitride (TiAlN) coated and uncoated tool. Relationship between the machining variables and the output variables is analyze and the tool that performs better were selected so that the experiments can be continue to prove the findings. It was observed that minimal delamination at entry and exit is achieved when using TIAIN at high spindle speed and feed.

**Keywords:** carbon fiber reinforced polymer, diamond coated tool, drilling, titanium aluminum nitride coated tool, uncoated tool.

## INTRODUCTION

Aircraft is made of materials that can withstand the mechanical failure at any point of time. It is not just a requirement but also for a safety of a life. Over the year, research were made to improve the structure of an aircraft so that it can provide the best high strength-to-weight ratio which ultimately reduce the fuel consumption and increase their performance accordingly. It has been reported that [1], weight saving aircraft is achieved by optimum fibre lay-up and skin thickness that tailored to the requirements of the specific location, this greatly increases fuel efficiency and performance of the aircraft. Ramesh *et al.* [2] proved that composite materials are continuously replacing conventional metals and alloys in many applications such as aircraft, automotive etc. The combination of superior mechanical properties such as high specific strength, stiffness and fatigue strength, enable the structural design more reliable than conventional metal. In example [3], Boeing 787 Dreamliner was the first world major commercial airliner that used composite materials for the construction of most of its parts. Cunningham [4] mentioned that, great care is expended on creating the structural joints of the aircraft because they are subject to high stresses. The holes are drilled with keen attention to making their axes normal to the skin surface and their diameters correct. If there is any possibility that drilling a hole will leave a delamination at entry and exit, it must be manually removed because it could puncture the corrosion-resisting paint when the skins are pulled together by the fastener. Surface defects always occur during machining of carbon fiber-reinforced polymer (CFRP). According to Konig *et al.* [5], CFRP when machined with conventional technique often results in high surface roughness, fiber damage, interlaminar failure, delamination at surfaces, high tool wear rate and high operating cost. Karpat *et al.* [6] reported that defects on the machined surfaces may cause the parts to be

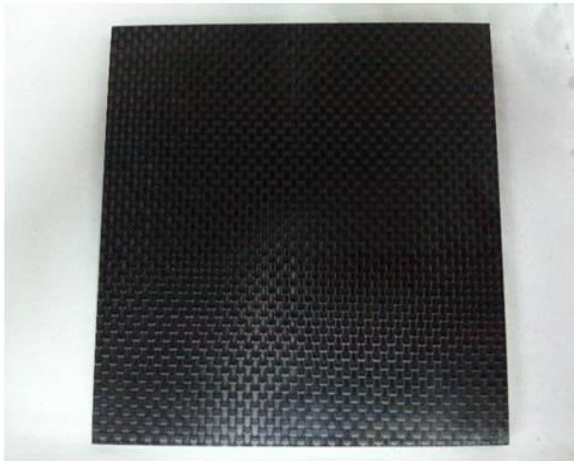
rejected and can lead to tool wear. In order to avoid the surface defects, some machining parameters need to be controlled. Although CFRP are lighter and stronger than materials that are typically being used such as steel and aluminum, they face a challenge when it comes drilling. It has been suggested that [7, 8, 9] drilling is the most often encountered machining process in the parts made out of fiber reinforced composites. The drilling induced delamination is a critical aspect as it can lead to the failure of the dynamic structure. It has been reported that [10, 11], the delamination was found to occur at tool entry (peel-up) or tool exit (push out). Previous studies shows that [12, 13, 14, 15, 16], delamination and surface finish in drilling composite materials have been found to be influenced by a number of factors such as feed rate, cutting speed, drill geometry, tool wear and tool material. This experiment was conducted to to study how machining parameters influence the production of delamination on drilled CFRP using diamond coated, titanium aluminium nitride (TiAlN) coated and uncoated tools on Mazak Vertical Center Nexus 410A-II machine with maximum rotational speed of 8000rpm. Fractional factorial design of experiments was employed for designing the experiments.

## EXPERIMENTAL DETAILS

This section describes the work-piece and cutting tool materials, the experimental conditions, setup and procedure.

### Work and tool materials, and experimental conditions

Plain type CFRP, with dimension of 110mm x 1100mm x 3.5mm, was used as the workpiece is shown in Figure-1. The tools chosen for the experimental work are 3mm-diameter diamond coated, TiAlN coated and uncoated tool is shown in Figure-2.



**Figure-1.** Plain CFRP workpiece.



**Figure-2.** Diamond, TiAlN and uncoated tools.

### Experimental conditions

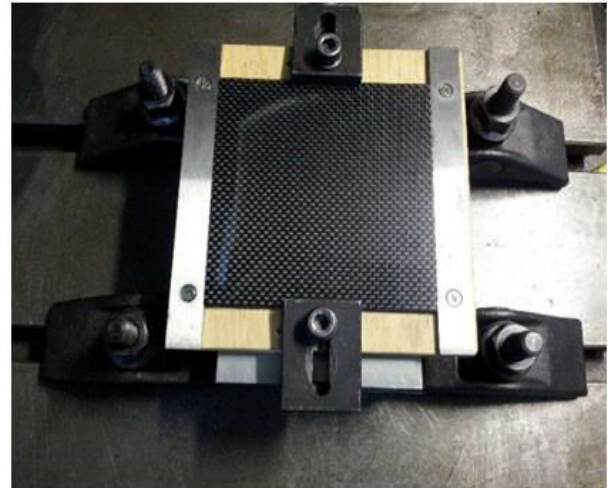
The machining variable for conducting the experiments are summarised in Table-1.

**Table-1.** Factors and levels in the design of experiments.

Factors	Levels		
	Low	Medium	High
Spindle Speed (rpm)	8000	5250	2500
Feed (mm/min)	250	325	400

### Experimental setup and procedure

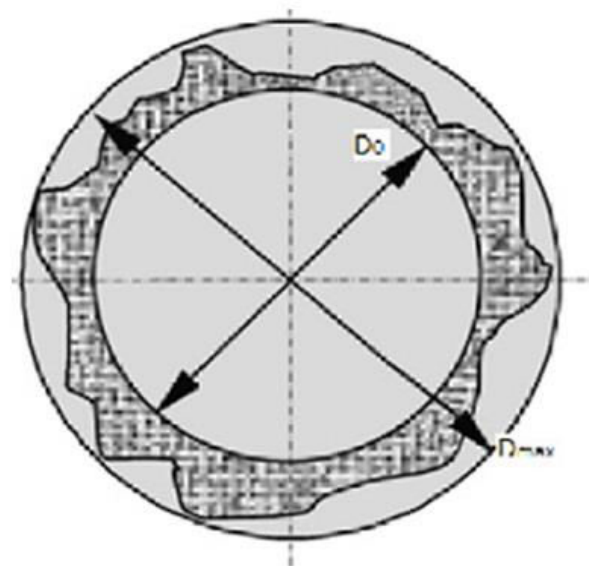
Figure-3 depicts the setup for the experiments on a Mazak VMC machines having maximum rotational speed of 12000 rpm. The plain CFRP were mounted on the jig prepared to ensure there is no movement allowed during machining. 27 experiment were conducted based on the Fractional Factorial experiment design.



**Figure-3.** Plain CFRP fixed onto the jig.

The dimension of drilled hole was measured by using Handheld Digital Microscope Pro, Celestron. Thus, following Gaitonde *et al.* [17], delamination factor was determined by Equation (1) and the  $D_{max}$  and  $D_o$  are illustrated in Figure-4.

$$Fd = D_{max}/D_o \quad (1)$$



**Figure-4.** Delamination factor scheme for CFRP composites drilling.

### RESULT AND DISCUSSION

The drilling experiments that were conducted to study the effects of machining parameters on delamination are listed in Table-2.

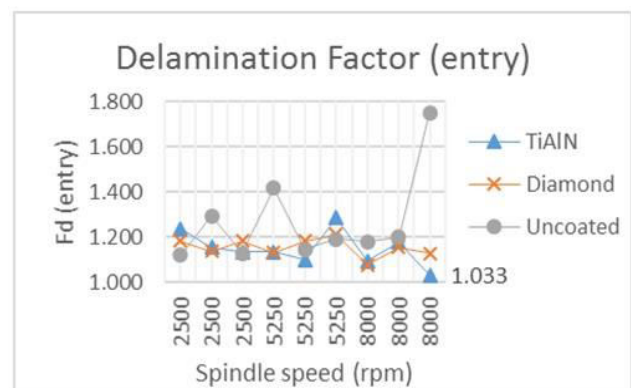


**Table-2.** Fractional factorial design showing 27 trial runs and response delamination.

		Factor 1	Factor 2	Factor 3	Response 1	Response 2
Std	Run	A:Spindle speed	B:Feed	C:Cutting tool	Delamination factor (entry)	Delamination factor (exit)
		rpm	mm/min	type	Fd	mm
23	1	5250	325	Diamond	1.131	1.310
12	2	8000	250	TiAlN	1.096	1.112
18	3	8000	400	TiAlN	1.177	1.068
9	4	8000	400	Uncoated	1.181	1.077
24	5	8000	325	Diamond	1.077	1.142
15	6	8000	325	TiAlN	1.033	1.143
17	7	5250	400	TiAlN	1.134	1.255
2	8	5250	250	Uncoated	1.418	1.114
7	9	2500	400	Uncoated	1.122	1.277
25	10	2500	400	Diamond	1.183	1.390
26	11	5250	400	Diamond	1.184	1.119
8	12	5250	400	Uncoated	1.147	1.559
4	13	2500	325	Uncoated	1.295	1.217
20	14	5250	250	Diamond	1.211	1.306
10	15	2500	250	TiAlN	1.238	1.214
27	16	8000	400	Diamond	1.156	1.348
22	17	2500	325	Diamond	1.137	1.292
21	18	8000	250	Diamond	1.128	1.112
1	19	2500	250	Uncoated	1.130	1.518
14	20	5250	325	TiAlN	1.102	1.492
11	21	5250	250	TiAlN	1.287	1.168
16	22	2500	400	TiAlN	1.154	1.239
13	23	2500	325	TiAlN	1.136	1.302
5	24	5250	325	Uncoated	1.193	1.191
6	25	8000	325	Uncoated	1.200	1.213
19	26	2500	250	Diamond	1.183	1.315
3	27	8000	250	Uncoated	1.751	1.370

### Analysis on Delamination Factor (Fd) vs. Spindle Speed

The result shows that the TiAlN tool performs better compared to diamond and uncoated at high speed. The result also generates lowest Delamination are at the both entry and exit as shown in Figure-5 and Figure-6.



**Figure-5.** Graph of delamination factor at entry.



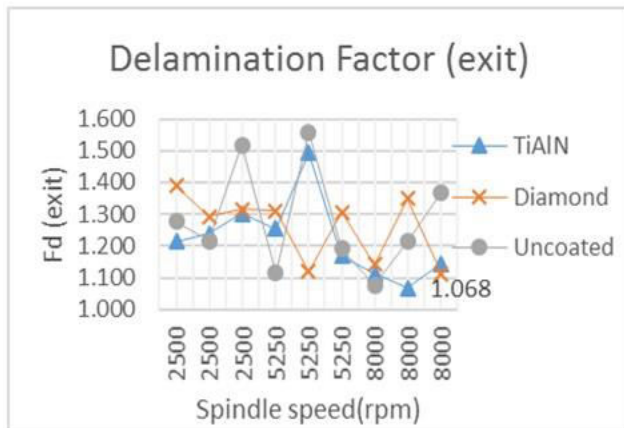


Figure-6. Graph of delamination factor at exit.

#### Analysis on Delamination Factor (Fd) vs. Feed

The result shows that the TiAlN tool perform better compared to diamond and uncoated at high feed. It also generates the lowest Delamination are at both entry and exit as shown in Figure-7 and Figure-8.

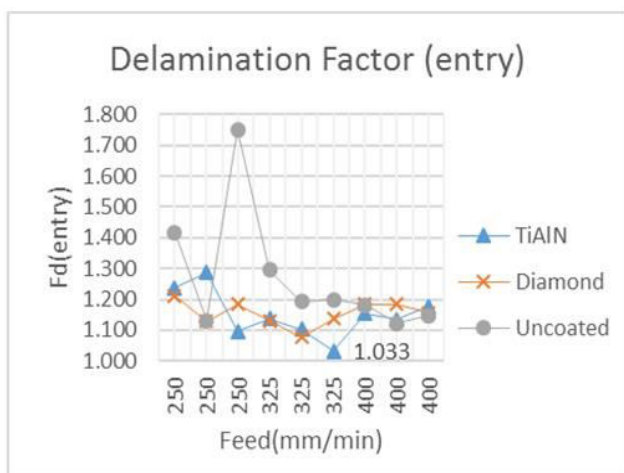


Figure-7. Graph of delamination factor at entry.

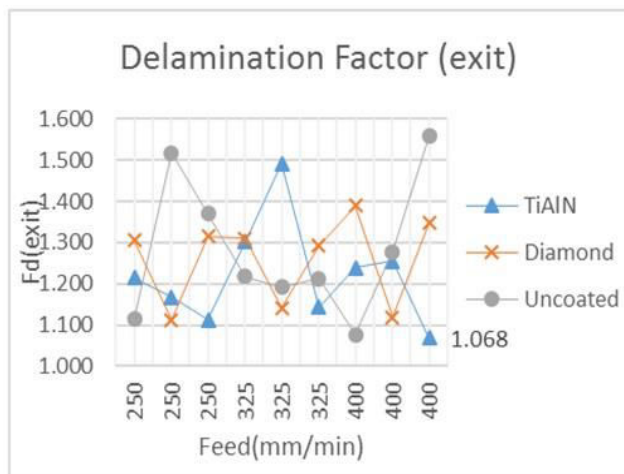


Figure-8. Graph of delamination factor at exit.

## CONCLUSIONS

The following conclusions can be drawn from the experiment that were conducted when CFRP was drilled with 3 mm-diameter Titanium Aluminum Nitride (TiAlN) coated tool:

- It has been observed that rotational speed, feed and coating tool type have marked effects on delamination.
- The delamination at both entry and exit will be at minimum when cutting speed and feed is high.
- When drilling with TiAlN coated tool, the combination of high spindle speed and high feed rate produce lowest delamination at both entry and exit.
- TiAlN tool has been selected to be the ideal tool for machining CFRP as it not only produce better results compared to diamond coated tool but also economically cheap.
- Further experiments is suggested to prove the findings.

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